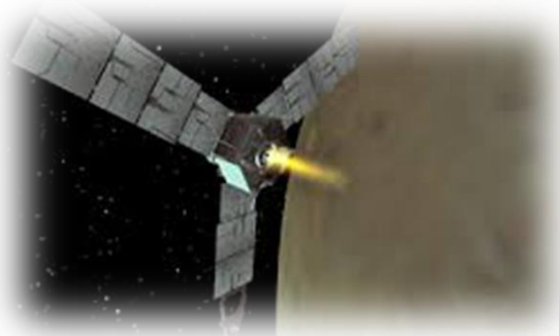
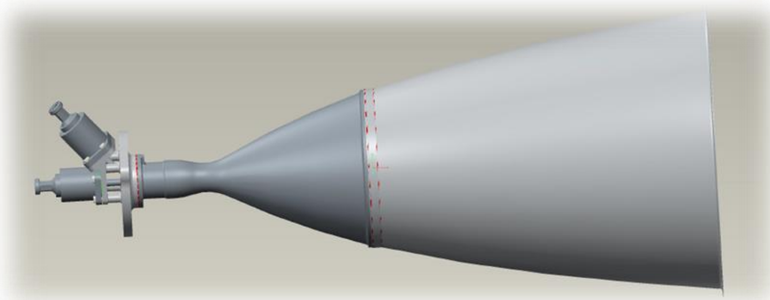
Nammo Westcott Ltd & ESA

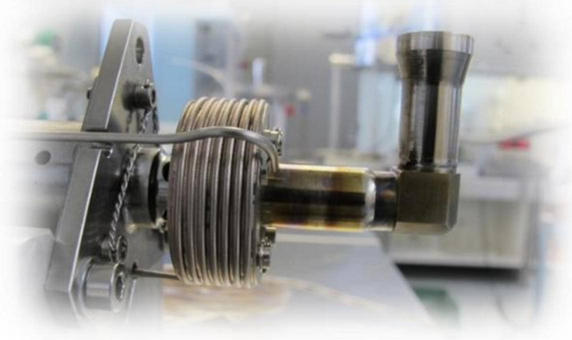
Electronic Pressure Regulator

26th October 2017

Adam Watts







SECURING THE FUTURE

Our New Owners ...

Nammo of Norway became the owners of the formerly Moog UK Westcott Ltd company on 9th June 2017.

Nammo has more than 50 years of experience in designing and manufacturing advanced rocket motors and products for space applications.

The acquisition of the Westcott chemical rocket company and their facilities enables both organisations to develop products and business in European and global space propulsion.

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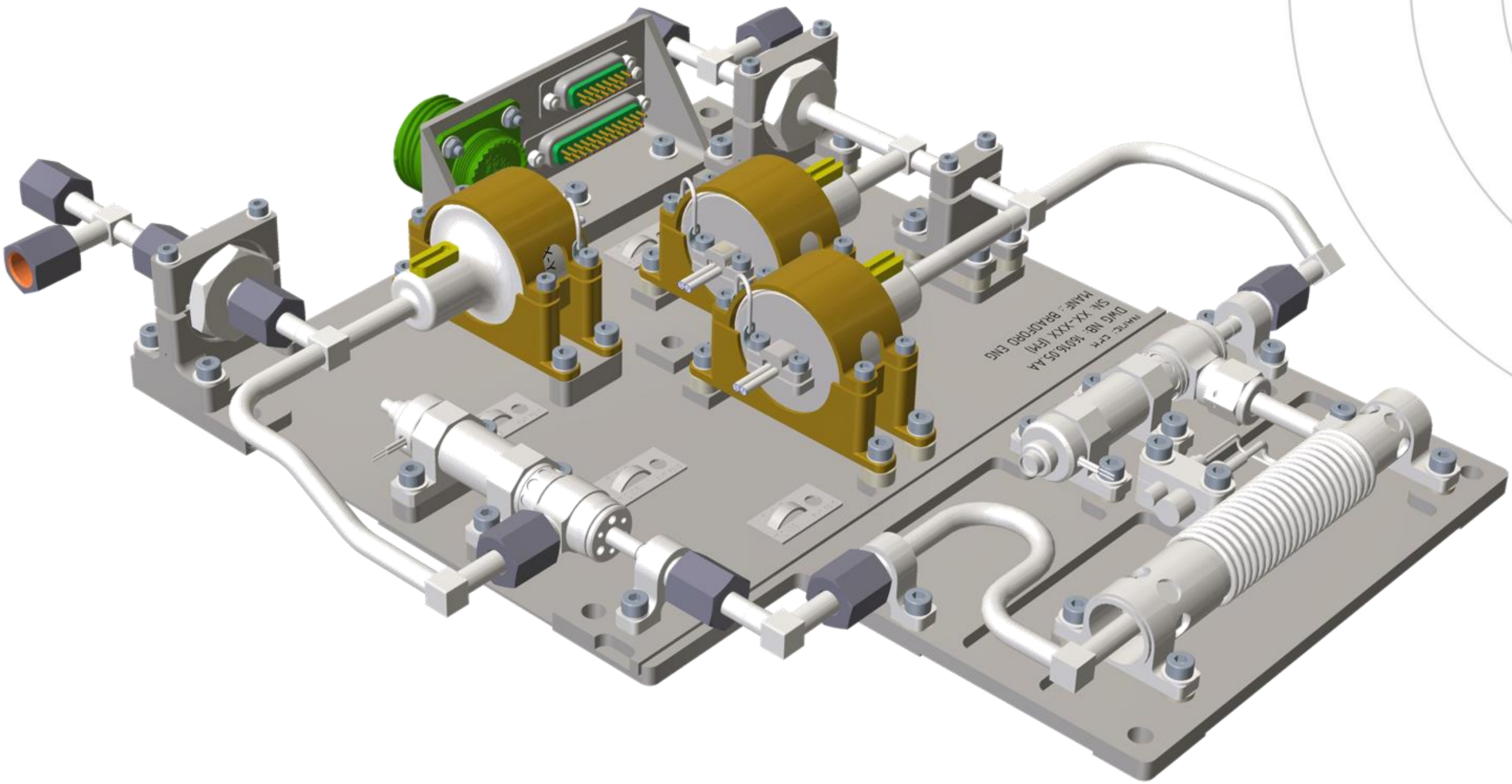
The Electronic Pressure Regulator

- The Electronic Pressure Regulator development at Nammo Westcott is aimed at enabling in-space pressure regulation and variability of pressure as required for Xenon, Helium and Nitrogen cold gas.
- This is a totally European product.
- The regulator is based on a new fast response valve design, which is a proportional device using a piezo actuator and is designed for a maximum operating pressure of 310bar as required for helium re-pressurisation control. This gives the valve excess design margin for xenon applications. The flow range is from zero to 600mg/s for Xenon and zero to 2g/s of helium.
- A pressure sensor is fitted downstream of the valve, providing a fast response feedback signal to an electronic controller which drives the valve to maintain the required pressure and any operational flow rate.
- For the Xenon application an integral heater is used to raise the temperature on the upstream side of the valve and prevent the Joule Thompson two phase flow effecting regulation performance.

Electronic Pressure Regulator System

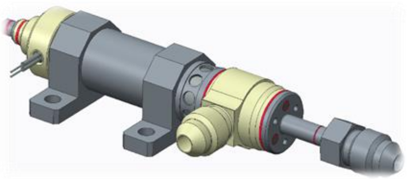


Benefits of Electronic Pressure Regulation

- In-flight pressure variation and control throughout mission life.
- Programmable by telecommand.
- Compatible with all heritage spacecraft propellants and pressurants.
- Suitable for flow control of liquids and gases.
- Regulation accuracy of <0.05 bar (mechanical regulation is typically >0.2 bar).
- Response to 90% of new level <1 second.
- No need for multiple regulators (as in the mechanical case).
- Low leak rate (<2 x 10^{-5} scc/sec Helium internal).
- High Flow capacity > 600mg/s Xenon at EoL, >2g/s Helium at EoL.
- Up to 310 bar MEOP.
- Pressure set point range is 0.5 to 22 bar.
- In-orbit data logging.
- The Nammo EPR system design for Electric Propulsion applications includes thermal conditioning of Xenon (or Nitrogen) to prevent Joule-Thompson issues and regulate outlet pressure & minimum temperature.

The Electronic Pressure Regulator – Commercial

- There is significant interest in Electronic Pressure Regulation from many customers now they know it is at Engineering Model stage.
- The ESA Clean Space team is supporting this development and we are looking to take the EPR system through to Qualification in 2018.
- No doubt this EPR will be considered alongside mechanical regulation on purely a cost equivalence basis. Our task is to ensure everyone knows the overall propulsion system and controllability advantages are clearly communicated to customers.



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Statement of Work – Current Status

- **7.1 Task 1 - Requirements assessment**

The objective of task 1 was to identify and report requirements for the proposed range of applications covering electric and chemical propulsion and to perform a trade-off of potential technical solutions.

✓

- 7.2 **Task 2- Unit design definition**

The objective of task 2 was to perform the unit design activities, including development of a fluidic performance model and baseline design configuration.

✓

Statement of Work – Current Status

Task 3 -Detailed design and manufacturing preparation

The objective of task 3 was to perform the detailed design of the Engineering Model fluidic unit and Breadboard Model electronics and to prepare the manufacturing process flow and process definitions.

- 7.4 **Task 4 -Manufacture, assembly and test**

The objective of task 4 is to manufacture, assemble and test the Engineering Model of the fluidic unit and the Breadboard.

Model electronics defined during tasks 1 to 3.

The High Pressure Proportional Valve is currently undergoing initial testing for leak rate and flow rates across the pressure ranges. Results are extremely encouraging and exciting.

Statement of Work – What Next

- **7·5 Task 5 - Review of design and development planning to qualification**

The objective of task 5 is to review the design in terms of its compliance to the requirements and to prepare a development plan to cover any modifications to the design necessary to achieve qualification. The development planning shall cover all activities necessary to formally qualify the product and shall including ROM non-recurring cost estimates and target recurring price.

The High Pressure Proportional Valve – Heart of the EPR

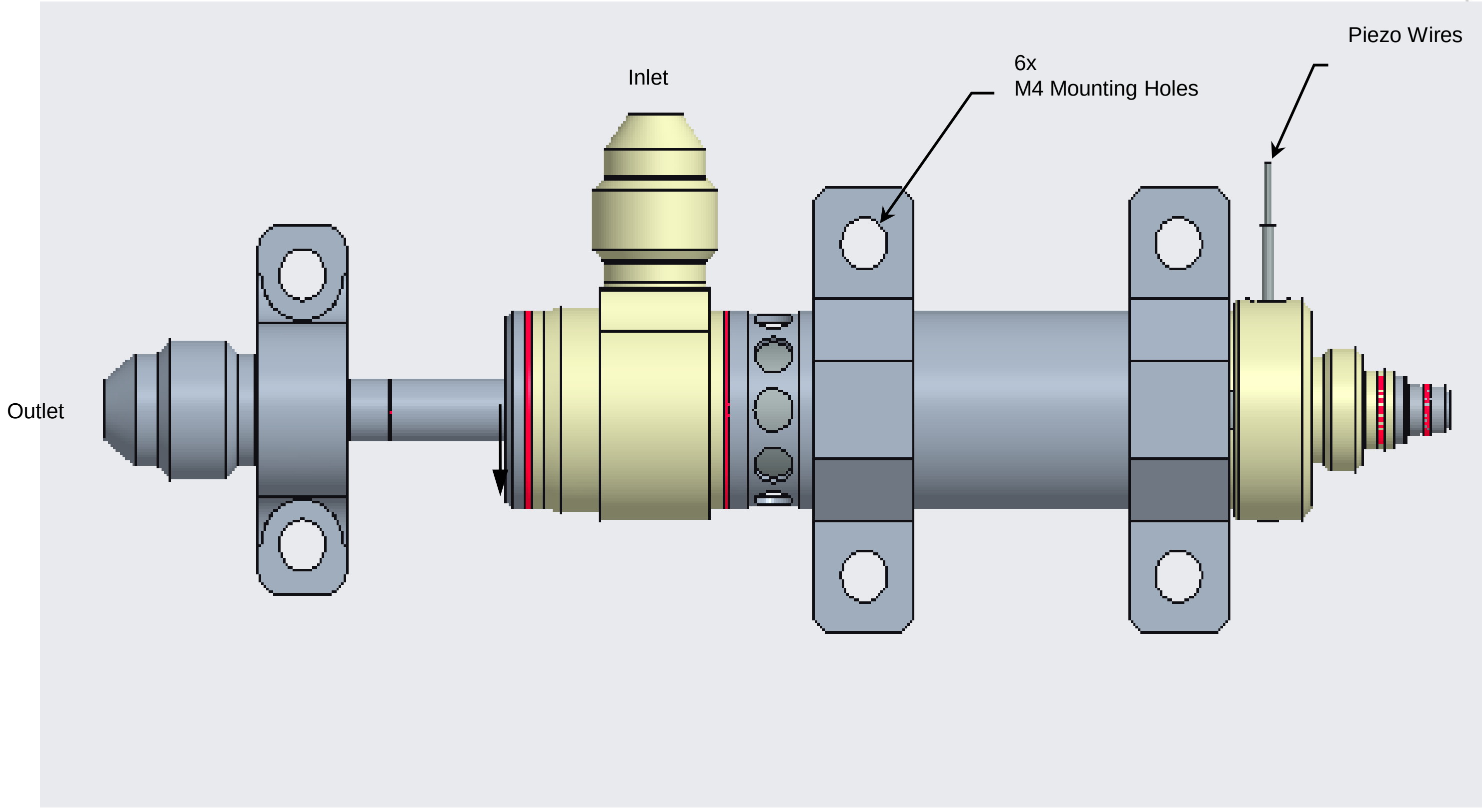
- The High Pressure Proportional Valve (HPPV) is the key enabling component for electronic pressure regulation.
- This valve incorporates an innovative and state-of-the-art operational mechanism that includes unique temperature compensation that is achieved through carefully balanced internal component coefficients of thermal expansion (CTE).
- The HPPV reduces the pressure from the tank to the requested low pressure requirement and regulates the pressure while maintaining the flow demand as required downstream.
- Hence the proportional valve inherently has a throttling capability, such that any flow rate can be achieved in the operating range through application of a steady input voltage.

The High Pressure Proportional Valve cont...

- Thermal compensation is included in the valve to prevent leakage and over stressing the seat when the valve is at non-operating temperature extremes.

- Materials in the HPPV are selected with low Coefficient of Thermal Expansion (CTE) values so that the thermal strains are low. The valve body and tension tube are made from Titanium alloy Ti-6Al-4V.

The High Pressure Proportional Valve



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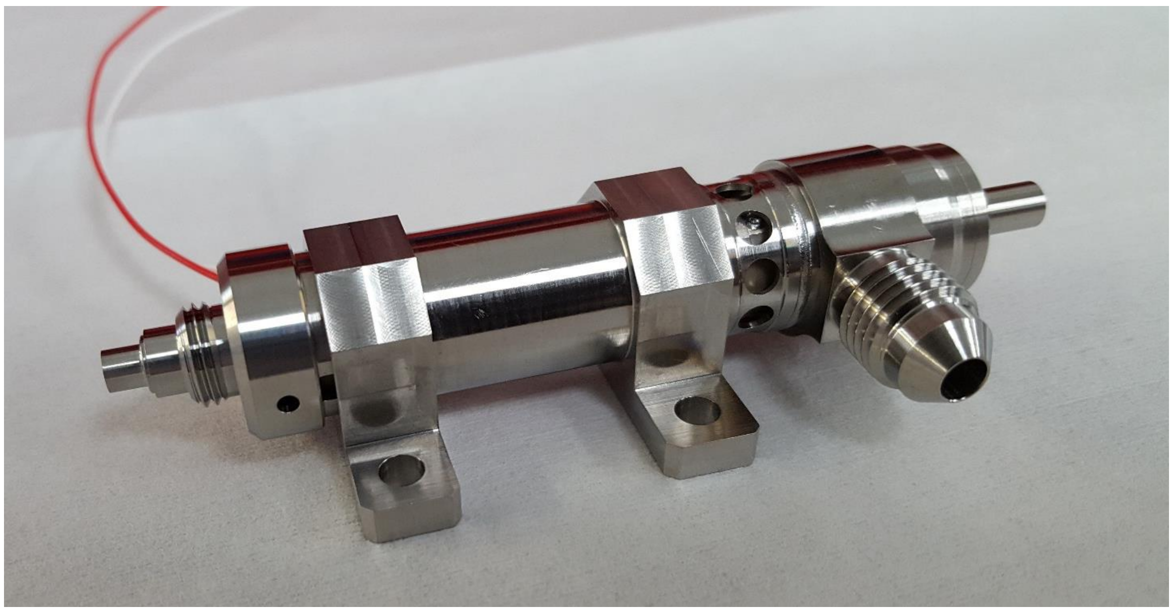
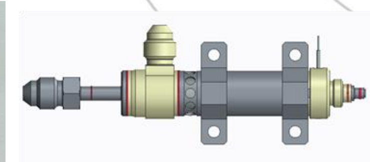
HPPV – Manufacturing Readiness

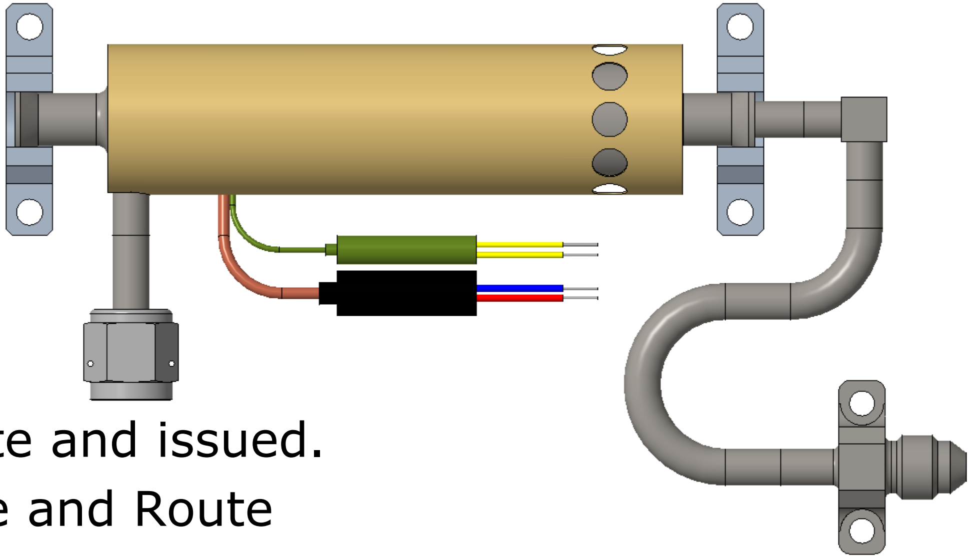
- All drawings are complete and issued for both the HPPV and the required production tooling.
- Manufacturing Procedure and Route Cards are in place.
- All parts are manufactured and the first HPPV is assembled and undergoing testing.





Heater for Xenon Pressure Regulation

- When used in a Xenon or Nitrogen application the EPR requires a propellant heater to avoid two phase flow in the regulator caused by Joule Thompson cooling. The EPR design uses a heater upstream of the high pressure proportional valve, which heats the gas so that the outlet gas (at LP node) is maintained above 27°C.
- The Heater performance has been proven via breadboard testing and the design is finalised.



- All drawings are complete and issued.
- Manufacturing Procedure and Route Cards are prepared.

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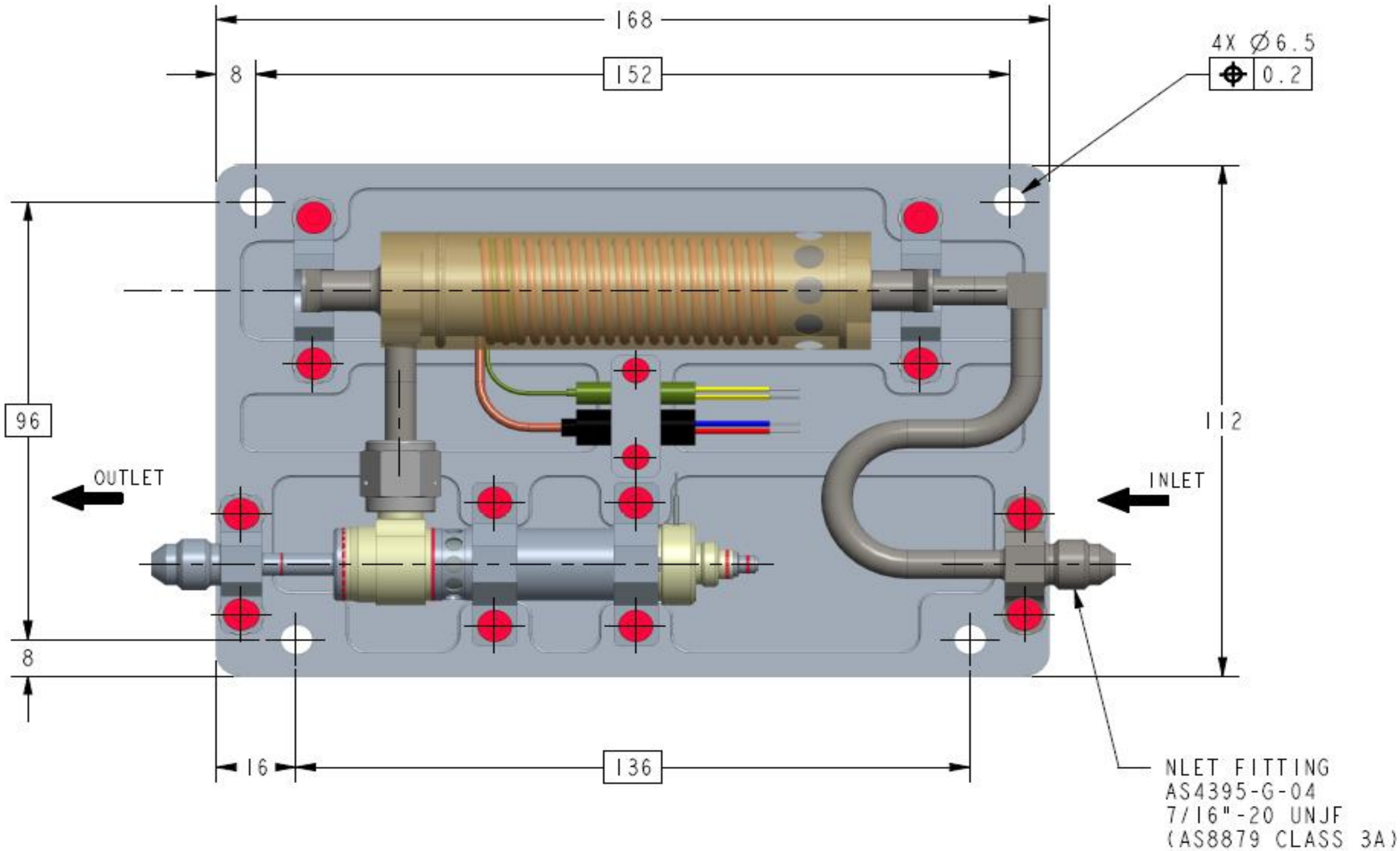
HPPV & Heater Sub-Assembly – Layout & Sizing



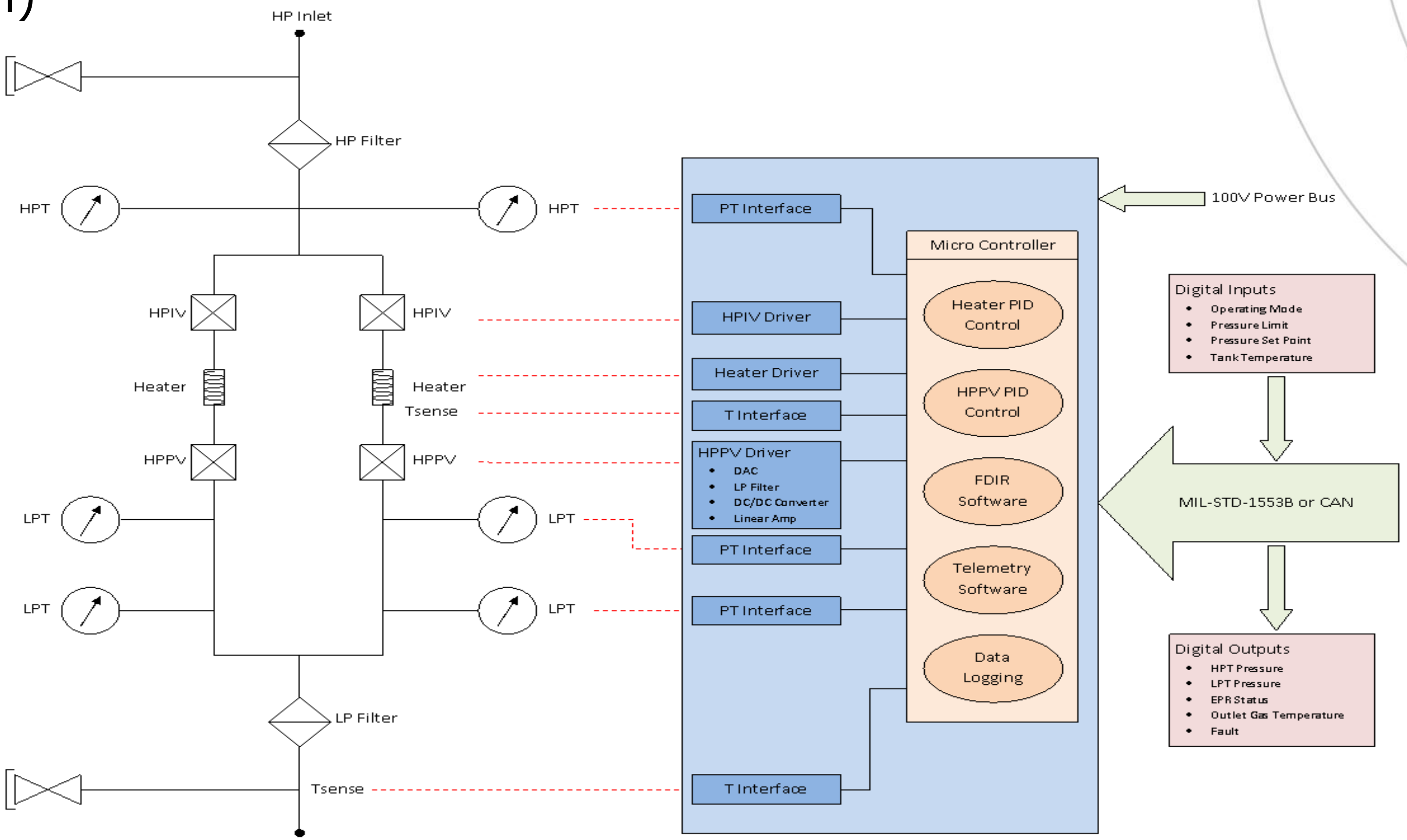
The Electronic Pressure Regulator

- Electronic Pressure Regulator (EPR) system for propellant or pressurant supply which regulates the pressure from a spacecraft storage tank to any requested lower pressure within a specified range. The precisely regulated low pressure output of propellant or pressurant from the EPR supplies the spacecraft thrusters or propellant tank to suit the mission requirements.

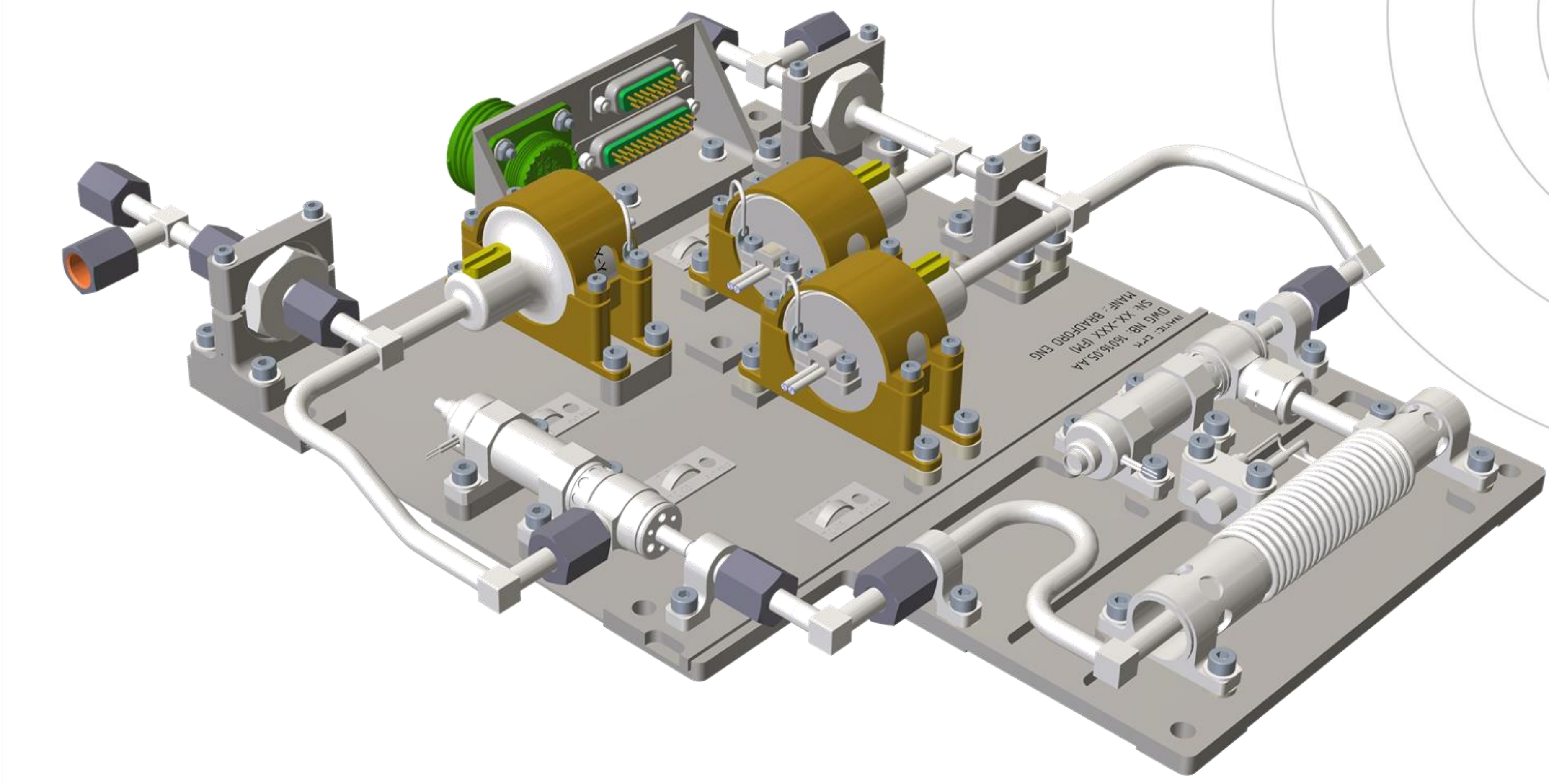
- The EPR consists of a fluidic part which performs the flow control and isolation of the fluid and an electronics module which communicates with the spacecrafts on board computer as well as controlling the isolation valves, heaters and monitoring the pressure and temperature sensors. The system has a primary and secondary branch which provides dual redundancy with no 'cross-strapping' of power or signals between the two independent branches.

EPR for Xenon

This is a system schematic for the Xenon case (incorporates propellant heater to eliminate the Joule Thompson Effect issues encountered with Xenon)



Electronic Pressure Regulator System (Xenon case)



Parameter	Value
Operating Media	Xenon, Nitrogen & Helium.
Maximum Operating Inlet Pressure	310 bar (Helium & Nitrogen) 187 bar (Xenon)
Regulated Outlet Pressure Range	0.5 to 5 bar Abs (Xenon & Nitrogen) 13 to 22 bar Abs (Helium)
Internal Leakage	< 2 x 10^{-5} scc/s GHe
Xenon Mass Flow Range*	0 to 600 mg/s, P1 = 187 to P2+10bar (TBC) 0 to 80 mg/s, P1 = 187 to P2+0.5bar (TBC)
Helium Mass Flow Range*	0 to 600 mg/s, P1 = 310 to P2+10bar (TBC) 0 to 2000 mg/s, P1 = 310 to P2+60bar (TBC)
Pressure Ripple	0.1bar/s (Xenon) 0.15bar/s (Helium)
Overshoot (step change in flow rate to zero)	0.4bar
Regulation Accuracy	< 0.05bar
Downstream Volume	< 300cc (Xenon & Nitrogen) < 1000cc (Helium)
Thermal Control	Active control to prevent phase change effecting flow stability (Xenon & Nitrogen)
Outlet Temperature	+17 to +27° C (Xenon)
Mass Throughput	1500kg (Xenon)
Mass	Fluidic < 5Kg Electronics < 2Kg
Temperature Range	-30° C to +60° C